

the computer display **42**, with any differences between the detected and designed images highlighted or otherwise indicated as defects in the X-ray mask. Having thereby initially detected an error or defect, the magnification of the electron microscope **17** may be zoomed in for closer observation of areas on the mask **22** which exhibit anomalies. In this way, the exact coordinates of defects can be recorded, and stored in the computer memory **46**, for later transfer to a repair instrument (typically a focused ion beam). A high resolution X-Y stage (not shown) may be combined with the inspection system **15** to support the mask **22** and to facilitate determination of anomaly coordinates.

It is apparent that the method of inspecting an X-ray lithography mask of the present invention that has just been described is performed under the same operating conditions as will be employed during actual exposure of a photoresist using the X-ray mask. Thus, errors introduced by inspecting the mask using radiation of other wavelengths and having different penetration and diffraction characteristics are avoided. Also, the present invention is capable of probing the bulk of the mask structure, as well as the absorbers **26** deposited on the mask **22**, rather than probing only the surface features, as is the case in other mask inspection systems. The present invention forms an image from the actual X-ray transmissions of the mask **22**, which is the quantity most relevant to the mask's performance in the X-ray lithography process.

The mask inspection system **15**, and method of mask inspection just described, may also be employed in the inspection of EUV masks and EUV steppers used in EUV lithography. In EUV masks, X-ray absorber patterns **26** deposited onto X-ray transmissive materials are replaced with patterns of EUV non-reflective materials overcoated onto a multilayer EUV reflector which absorbs EUV rays impinging on the reflective mask from, in this case, an EUV source **30** (using the same reference numerals for the corresponding elements of the EUV mask system and the X-ray mask system). For device production using EUV lithography, a photoresist, which is sensitive to the EUV radiation impinging thereon, is exposed through an EUV stepper (not shown). The pattern of the reflective EUV mask **22** is thereby transferred to the photoresist, which is then developed to remove areas of the photoresist to match the mask pattern. Electronic or micromechanical structures are then formed on a substrate in the patterned area of the photoresist. Defects **28** in the EUV reflective mask will thus cause errors in the photoresist pattern, and defects in the resulting electronic or micromechanical structure.

Inspection of an EUV mask in accordance with the present invention is accomplished in essentially the same manner as the X-ray mask inspection as described above. The EUV mask is placed in its proper position in the EUV stepper. The converter layer **18** of the inspection system **15** is then placed at the wafer plane of the stepper. Alternatively, the converter **18** may be held in close proximity to the mask to directly map the light intensity. Since the mask features are relatively large (i.e., 4 or 5 times the critical dimension) a faithful image can be obtained at a distance between the converter **18** and the mask **22** of around 0.5 μm . EUV rays passing through the stepper impinge on the converter **18**, which emits electrons **32** whose intensity is related to the intensity of UV rays passing through the mask **22**. The electrons **32** are converted to an image of the mask pattern, which may be displayed and analyzed as described above using the computer comparison and display system **20**. In the case of EUV mask inspection, defects **34** become apparent as errors in the image.

The inspection system **15** of the present invention may also be used to perform X-ray and EUV inspection of objects other than lithography masks. For example, a sample including biological or other structures may be placed in the position of the mask **22** between the X-ray or EUV source **30** and the photo-emitting cathode **16**. Radiation passing through the sample may be absorbed by some portions of the sample and not by other portions of the sample. Electrons **32** will be emitted by the converter **18** in a pattern whose intensity is proportional to the local intensity of radiation impinging thereon. The electrons are then magnified by the electron microscope **17**, and the resulting image may be displayed on the computer system **20**. In this manner, the X-ray or EUV transmission or absorption characteristics of the sample may be observed and analyzed using the inspection system of the present invention.

It should be noted that the present invention is not limited to the particular embodiments or applications as set forth herein as illustrative, but embraces all such modified forms thereof as come within the scope of the following claims.

What is claimed is:

1. Apparatus for the inspection of an X-ray mask including an X-ray transparent substrate layer that allows X-rays to pass relatively unimpeded therethrough and X-ray absorbers positioned on the substrate layer in an absorber pattern through which X-rays are passed in a pattern, comprising:

- (a) a converter positioned to receive the X-rays in the pattern passed through the X-ray mask and to convert the pattern of X-rays received to a pattern of electrons emitted from the converter with the local intensity directly proportional to the local intensity of the X-rays impinging on the converter;
- (b) an electron microscope positioned to receive the electrons emitted from the converter and having electron optics therein to magnify the pattern of electrons and provide a visible display of the magnified pattern;
- (c) a camera receiving the visible display and providing an output signal corresponding thereto;
- (d) a computer receiving the output signal and digitizing the output signal;
- (e) a display connected to the computer to display the digitized image from the computer;
- (f) means for storing a digitized as desired pattern of the X-ray mask; and
- (g) means for comparing the as designed pattern to the digitized image.

2. The apparatus of claim 1 wherein the converter comprises a thin film phosphor deposited on a membrane to form a photo-emitting cathode.

3. The apparatus of claim 1 wherein the electron microscope comprises a photo-emission electron microscope including an electrostatic imaging column, a microchannel plate image intensifier with the electrostatic imaging column outputting an enlarged photo-emission yield picture of the pattern of electrons emitted from the converter onto the microchannel plate image intensifier, and a phosphorous screen, with the electrons being accelerated by the microchannel plate image intensifier onto the phosphorous screen to convert the photo-emission yield distribution into a visible image.

4. The apparatus of claim 1 including data memory connected to the computer for storage of the digitized image.

5. The apparatus of claim 1 including an X-ray source providing X-rays that are passed through the object.

6. The apparatus of claim 5 wherein the X-ray source is a synchrotron.